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ABSTRACT

Findings from a 4-year study of exemplary science and mathematics programs for middle school students with limited English proficiency (LEP) are presented. The four programs described here provide stimulating mathematics and science curricula through instruction in either the students' native language or in English using sheltered techniques. Common program characteristics include these: (1) all were manifestations of larger national and state-level efforts to improve mathematics and science instruction; (2) the exemplary science and mathematics programs took place in a broader context of school restructuring; and (3) well-conceived and well-implemented language development programs for LEP students were crucial to program success, and included qualified faculty, multiple-program pathways for transition to English, and support for transitioning students to all-English instruction. Contains seven references. (MSE)

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EDUCATIONAL PRACTICE REPORT: 17

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LEARNING SCIENCE AND ENGLISH: HOW SCHOOL REFORM ADVANCES SCIENTIFIC LEARNING FOR LIMITED ENGLISH PROFICIENT MIDDLE SCHOOL STUDENTS

CATHERINE MINICUCCI

U.S. DEPARTMENT OF EDUCATION
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Learning Science and English: How School Reform Advances Scientific Learning for Limited English Proficient Middle School Students

Catherine Minicucci
Minicucci Associates
Sacramento, California

National Center for Research on Cultural Diversity and Second Language Learning

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Barry McLaughlin and Roland Tharp, Co-Directors
National Center for Research on Cultural Diversity
and Second Language Learning
Social Sciences II
1156 High Street
University of California
Santa Cruz, CA 95064

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Overview

This article presents findings from the School Reform and Student Diversity Study, a 4-year project to locate and analyze schools offering exemplary science and mathematics programs to middle school students with limited proficiency in English. In contrast to the vast majority of schools, the four schools described in this article give these students access to stimulating science and mathematics curricula by instructing them either in the students' primary language or in English using sheltered techniques. These schools have overcome the usual barriers to including students with limited English proficiency (LEP) in grade level science and mathematics courses, particularly the belief of many teachers and administrators that fluency in English is a prerequisite to learning other academic subjects.

How have these schools been able to offer innovative science and mathematics programs to students who are not yet proficient in English? First, these programs were manifestations of larger national and state level efforts to improve science and mathematics instruction. External partners connected the schools to these larger reform efforts and aided teachers in developing thematic instruction, providing hands-on experiential learning opportunities, and fostering students' construction of meaning. Second, the exemplary science and mathematics programs took place in a broader context of school restructuring, such as school-based decision making in regard to allocation of resources, creation of smaller school units for learning, innovative uses of time that protected and extended LEP students' time to learn, and teacher collaboration. Finally, well-conceived and well-implemented language development programs for LEP students were crucial to the programs' success. The availability of qualified faculty, the creation of multiple-program pathways for transition to English, and support for transitioning students to all-English instruction provided the foundation for giving LEP students access to innovative science and mathematics programs.

Introduction

At least one in five children in U.S. schools comes from a language minority household, where a language other than English is predominantly spoken. For many of these children, English is not their first language, and they enter school with limited English proficiency (LEP). Programs to assist students in learning English and other academic subjects have traditionally focused on students at the elementary school level, with the assumption that most LEP students enter school in the early elementary grades. However, educators have increasingly recognized that a substantial number of LEP students first enter U.S. schools in the upper elementary grades or in middle or high school. In California, for example, 31% of LEP students in 1991 were secondary school students (California State Department of Education, 1991, cited in Lucas, 1993).

Like their grade school counterparts, LEP secondary school students are likely to attend schools in poor neighborhoods and to be at significant risk for dropping out of school. In addition, they face formidable challenges in gaining access to an academic program equivalent to that offered to students who are proficient in English. A survey of secondary schools in California found that few schools offered a complete program of academic courses to LEP students (Minicucci & Olsen, 1992). Thus, students at the secondary school level who are not proficient in English often are unable to take enough courses, or the required courses, to graduate from high school or qualify for college. In particular, students who do not begin a sequence of science and mathematics courses at the beginning of secondary school are seldom able to pursue occupations requiring a scientific background.

At the same time, the nation is becoming aware of the need for all students to become scientifically and mathematically literate. Fundamental change in the way science and mathematics are taught has been a cornerstone of school reform (Anderson, 1994). Reform advocates call for students to learn the scientific method by doing science: performing experiments, observing natural phenomena, and formulating conclusions based on evidence. In this way, students learn that there is not necessarily one right answer, but many paths to many right answers and that teachers are not the sole source of all wisdom, but rather that students can learn things for themselves, with their peers or through systematic observation.

There are few guidelines for schools to follow in designing this kind of science and mathematics curriculum for LEP students. This educational practice report describes a 4-year research project[1] to identify and analyze exemplary school programs that offer LEP students access to the same kinds of challenging curricula as are available to students already proficient in English. This paper describes science programs in four middle schools. The project also examined four elementary schools that offer exemplary language arts programs to LEP students; those programs are described in

Learning English: How School Reform Fosters Language Acquisition and Development for Limited English Proficient Elementary School Students (Nelson, 1996). The schools profiled in this report illustrate how school reform, combined with high-quality programs for LEP students, support science learning in grades 6 through 8 by students who are native speakers of languages other than English.

Method

To select sites for the research project, the study team solicited nominations of exemplary schools offering mathematics and science to LEP students in grades 6 through 8 or language arts in grades 4 through 6 from knowledgeable people at the national, state, regional, and local level. In all, 156 schools were nominated from the 20 states with the largest populations of LEP students.[2] Approximately two thirds of the 156 nominated sites were language arts sites and one third were mathematics or science sites.

The study team screened 75 of the most promising sites using telephone interviews to identify schools that exhibited excellence in three areas: high-quality language arts, mathematics or science programs for LEP students; significant school restructuring, with respect to governance, organization of teaching, and uses of time; and implementation of a well-designed English language acquisition program.[3]

The results of the telephone interviews were used to create a pool of 25 schools with potential for in-depth study. From that pool, demographic, geographic and programmatic variables were used to select 15 schools for a one-day preliminary visit. One-day visits by one or two fieldworkers to the 15 sites provided information that allowed the final selection of eight case study sites. Four sites offered exemplary math and science programs; four offered language arts.

Data on student outcomes that are comparable across the sites were not available, particularly because LEP students are often not given the standardized tests (in English) that districts or states require of most students (Berman, Chambers, Gandara, McLaughlin, Minicucci, Nelson, Olsen, & Parrish, 1992). Therefore, the research team could not provide evidence of significantly higher student achievement scores to demonstrate quantitatively that the case study sites were exemplary. Nevertheless, the nomination, screening, and field visits all led to the conclusion that these schools were highly innovative and followed practices that were considered by researchers to provide outstanding learning opportunities for LEP—and all—students.

At each case study site, a team of three to four researchers spent 3 to 4 days at the school, interviewing the principal, site administrators, and

teachers; observing classes; and conducting focus groups with LEP students and parents of LEP students. District-level officials were interviewed at each site as were representatives of an external partner if the school had one. External partners included nonprofit organizations, federally-funded science projects, private curriculum and staff development organizations, corporate-sponsored organizations, and Schools of Education.

Barriers to Learning Science and Mathematics

The search for exemplary schools providing mathematics and science to LEP students was difficult and revealed some fundamental problems in schooling for LEP students. In most cases, state and district directors of second language programs were not familiar with exemplary mathematics or science instruction for LEP students and had not been closely involved with their state or district's efforts to upgrade science and mathematics education. Most legal, programmatic, and professional development emphasis of bilingual education has been at the elementary school level. State laws governing LEP students in grades 7 through 12 tend to be more general than those affecting students at earlier grade levels, and there are fewer models of effective programs for secondary school LEP students than elementary models (Minicucci & Olsen, 1992).

The study team also solicited nominations from experts involved in national, state, and regional efforts to upgrade science and mathematics education for middle school students. But few persons engaged in those efforts were familiar with the educational needs of LEP students. In some cases, they conceived of LEP students as belonging to a larger group of "disadvantaged" students and did not specifically consider the language development issues confronted by teachers educating LEP students. The dilemma can be put in simple terms: the educational experts who concerned themselves with LEP students were not familiar with efforts underway to upgrade science and mathematics learning, and the educational experts who concerned themselves with upgrading science and mathematics learning were not familiar with educating LEP students.

Often, experts would nominate schools that met two of the criteria: For example, the school was implementing an innovative science program, and the school enrolled a large number of LEP students. In many of these cases, further questioning revealed that LEP students were not participating in the school's innovative science program. This finding is consistent with that suggested by a California study that showed that most secondary schools do not teach grade-level science to LEP students (Minicucci & Olsen, 1992).

The reasons for not including LEP students usually involved one of three factors. First, the vision of the new science curriculum did not include LEP students and those developing the curriculum were not knowledgeable about LEP student needs or programs. These individuals often regarded fluency in English as a prerequisite to learning science. The second barrier

to LEP student participation in innovative science curriculum was the lack of appropriately trained faculty to deliver the instruction in the primary language of LEP students or to use appropriate sheltered instruction methods. Even if schools conceptualized the science program as potentially beneficial to LEP students, they did not know how to deliver the instruction in a manner the LEP students could understand. For example, a middle school with a student population that was almost 100% Hispanic and 50% LEP received an $800,000 science curriculum grant. Curriculum developers wanted to involve LEP students, but there were not enough trained personnel to do so. Advanced LEP students were selected to translate the material for other LEP students, but this approach was cumbersome and eventually was abandoned. As a result, LEP students did not receive access to the science curriculum, which had been specially developed to motivate Latino inner city youth to learn science.

The third barrier is the lack of systematic time for teachers to plan together how to implement new curricula. This barrier applies across the board to teachers of LEP and non-LEP students. Teachers need time to learn about new approaches to teaching as well as time to plan thematic instruction, experiments, expeditions, and learning activities. They need time to reflect with one another after trying various new approaches in order to consider what worked and what did not work, and to refine their instructional strategies.

Exemplary Schools

The four exemplary schools profiled in this report have been able to overcome these barriers by becoming involved with national and state efforts to upgrade science and mathematics curricula, by coordinating and integrating high-quality language development programs for LEP students with science and mathematics instruction, and by restructuring the school in ways that facilitate LEP students' learning. Table 1 provides demographic and programmatic information on the four schools, followed by a profile of each school.

Graham and Parks Alternative Public School

Graham and Parks School is a K-8 magnet school serving 365 students from different districts throughout the city of Cambridge, MA. Graham and Parks has been led for 19 years by the same principal who has acted as a guiding force in the school's educational vision. The district desegregation plan also shapes the school's program: Parents of English-speaking students choose the school through a lottery system and parents of Haitian Creole-speaking students choose the school because the district houses its Creole bilingual program there. The bilingual program serves Haitian immigrant students from kindergarten through eighth grade.

TABLE 1
EXEMPARY SCHOOLS OFFERING SCIENCE TO LEP STUDENTS

	Graham & Parks Cambridge, MA	**Hanshaw** Modesto, CA	**Horace Mann** San Francisco, CA	**Harold Wiggs** El Paso, TX
Enrollment	365	860	650	1,000
Grade structure	K-8	7-8	6-8	6-8
% LEP students	25%	29%	24%	28%
Language of LEP students	Haitian Creole	Spanish; Southeast Asian languages	Spanish; Cantonese; Other Chinese	Spanish
% students elig. free or reduced-price lunch	50%	94%	15%	73%
Science program	Inquiry based	Thematic instruction	Project-based learning challenges	Thematic instruction
External partner	TERC, Cambridge, MA	Susan Kovalik & Associates, Kent, WA	Project 2061	None for science; University of Texas at El Paso for mathematics
Funding for external partner	NSF, US Dept. of Education	Packard Foundation School's categorical aid funding	NSF; Carnegie, Mellon, MacArthur, Pew Charitable Trusts, Charitable Trusts Foundation, and more	Eisenhower funding supports Science 1 and 2 project in Texas (Texas Education Agency)

Most of the Haitian students at the school immigrated to the United States, some without their immediate families, as a result of the political upheaval in their home country. When these children entered Graham and Parks School, some were malnourished and many were unschooled and had no literacy in either Haitian Creole or English. The school provides special services for students and their families. For example, the Student Support Team—made up of the principal, assistant principal, teachers, a parent liaison, nurse, school psychologist, and interns—meets every Mon-

day and takes a case-study approach to students who are referred by staff. Counseling is also available at Cambridge Hospital and through a Haitian community counseling program. Graham and Parks is also staffed with a bilingual parent coordinator, a Haitian resource-room teacher, and Haitian mediation specialist. All of these services facilitate the students' transition to English and to life in the United States.

The Haitian Creole bilingual program is organized into multi-grade classes taught by bilingual teachers fluent in Haitian Creole and English. The program goals for language development include the acquisition of literacy in both Haitian Creole and English; it takes most students 5 or 6 years to become fully literate in English. The classes are grouped as follows: pre-kindergarten and kindergarten, first and second grades, third and fourth grades, and fifth through eighth grades.

The fifth through eighth grade bilingual program is taught by two teachers in one classroom. One of the teachers is Haitian-American, and he delivers all instruction in Haitian Creole. Because the range of development of English fluency varies among the students in this class, the teachers present important concepts in both English and Haitian Creole and students are allowed to choose eigher language to ask or answer a question. The switching between Haitian Creole and English seems natural and does not appear to interfere with the students' ability to learn either core content or English. Moreover, the combination of small class sizes (23 students with two teachers), the presence of two language role models in each classroom, and developmental, multi-year student grouping creates an environment that fosters language development by allowing students and teachers in the bilingual program to feel that they are part of a close-knit learning community.

The science program was developed collaboratively during the past 6 years by the Technical Education Research Center (TERC), a non-profit educational research firm located in Cambridge, and Graham and Parks teachers, under grants from the National Science Foundation and the U.S. Department of Education's Office of Bilingual Education and Minority Languages Affairs (OBEMLA) and Office of Educational Research and Improvement (OERI). Graham and Parks and several other schools in the Boston area serve as living laboratories for the development of TERC's "sense-making" approach to learning science.[4]

Researchers at TERC study what and how LEP students learn in an inquiry-based science classroom. In classes at Graham and Parks, science is viewed as a way of knowing and thinking, and students are encouraged to determine topics for study and to decide the questions to explore within a given topic. The TERC science lessons center around questions based on students' observations. Students seek to answer their questions using the scientific method.

Hanshaw Middle School

Hanshaw Middle School is a grade 6-8 middle school serving 860 students from a predominantly low-income Latino community in Modesto, CA. The school opened in the fall of 1991. Hanshaw students are 56% Hispanic, 26% White, 11% Asian, and 5% African American. After interviewing 500 families in their homes, the principal and faculty agreed on four principles for the foundation of Hanshaw's program: (1) high expectations for all students, (2) support for the Latino and Chicano experience, (3) a meaning-centered curriculum, and (4) a conscious effort to impart life skills as part of the curriculum. The principal recruited teachers from industry: A former carpenter teaches math, and a former children's museum director and a former wildlife biologist both teach science. Life skills such as patience, flexibility, integrity, initiative, and effort are taught at the start of each school year. Students are rewarded throughout the year for demonstrating life skills. Hanshaw also has a comprehensive health and social services center on campus staffed with social workers and counselors who are bilingual in Spanish and English.

Hanshaw is organized into five houses, each named for a campus of the California State University system. Each year students visit the college campus their house is named after, meet college students from various ethnic backgrounds, hear lectures, and receive a tee shirt and diploma. Students identify strongly with the college campus, which provides them with an alternative to gang affiliation.

Each house contains six to nine teachers led by a team leader. Teams of two teachers (one for the math/science core and one for the language arts/social studies core) teach a group of 30 to 35 students. All students take two 90-minute core classes, one for the math/science and one for the language arts/social studies. In addition, teachers within each house make decisions about their house's portion of the school's budget.

Hanshaw teachers make curriculum-design decisions based on a simple principle: The lesson or skill must be relevant to the students' lives. Teachers strive to help students know the "why" of an answer, or of multiple answers, or discover multiple ways of getting to an answer. Teachers build on students' own experiences in thematic instruction. Themes unify instruction across subject areas such as science, math, language arts, and social studies, incorporating topics from the curriculum frameworks of the state of California.

Hanshaw offers several programs for LEP students: Instruction in Spanish in core curricular areas, sheltered instruction for advanced Spanish-speaking LEP students and students who speak other primary languages, and mainstream English instruction for clusters of LEP students speaking the same primary language. When LEP students are considered ready to transition, they are clustered together in mainstream classes. Many of the mainstream class teachers have special training and credentials in

second language acquisition. LEP students receive challenging content in math and science taught in Spanish or in sheltered English.

Hanshaw teachers use a constructivist approach to teaching math. For example, a mainstream eighth grade algebra class included 15 LEP students. A spatial math lesson challenged students to modify the profile of a building and to graph the profile. Students working in cooperative groups used Lego blocks to recreate the profile in three dimensions. LEP students speaking the same language worked together in both English and their native language in their cooperative groups. The teacher's role was to set up the challenge and facilitate solutions to the problem by cooperative student groups. When students finished the assignment, the teacher, the former carpenter who had training in second language acquisition, asked them to solve it another way.

Hanshaw's program is supported by a vigorous relationship with an external partner, Susan Kovalik & Associates from Kent, Washington, which works with Hanshaw faculty in intensive summer and weekend retreats. A Kovalik coach assists the school on a monthly basis, designing curriculum, providing instructional coaching, and helping the faculty identify problems and solutions. The school purchases assistance from Kovalik with state and federal funds.

Horace Mann Middle School

Horace Mann Middle School in San Francisco, CA, enrolls 650 students in grades 6 through 8. Students choose the school in accordance with a districtwide open enrollment policy aimed at desegregating schools by limiting the enrollment of students from any one ethnic group. Spanish-surname students constitute 38% of the student body, Chinese students 14%, other White 20%, other non-White 13%, African American 9%, and Filipino 6%. Horace Mann is organized into six "families" of students, two at each grade level. Each family enrolls 100 students and has four core teachers. Students take their core classes (language arts, social studies, math, and science) in the family and electives and physical education outside the family. The school uses a block schedule in which students take two academic blocks each day, and each academic class meets every other day. The block schedule provides time for students to carry out in-depth research and project-based work without interruption. Each family offers an after-school program for students in need of extra help.

Within the families at Horace Mann, the students are clustered into strands of approximately 25 students with whom they take their core content courses. Spanish-speaking LEP students are served within the family structure in Spanish bilingual strands. Non-Spanish-speaking LEP students are also clustered in strands where they are taught in English by teachers trained in second language acquisition.

Horace Mann teachers develop pedagogical strategies based on the premise that all students learn best if they are actively engaged in

work that is meaningful to them. Elements of traditional content areas are integrated into thematic units with topics relevant to the students' lives. Student cooperative project topics have included: Feeding a hungry world; creating a non-violent community by the year 2000 for the San Francisco neighborhood of the school; and understanding the Chinese community in San Francisco.

Horace Mann students and faculty also participate in a national science reform effort, Project 2061, sponsored by the American Association for the Advancement of Science (AAAS). Project 2061, presents students with learning challenges that incorporate skills and knowledge from math, science, social studies, and language arts in a thematic approach. LEP students work as full members of a heterogeneous team, along with native English-speaking students, to meet the learning challenge. Project 2061 supports staff development, design of the learning challenges, and assessment of the success of student learning in challenges. Another important aspect of Project 2061 work is to document learning challenges so that they can be used in subsequent years with other students and teachers.

Harold Wiggs Middle School

Wiggs Middle School enrolls 1000 students in grade 6-8. As the first middle school in the El Paso Independent School District, and one of the first in Texas, Wiggs has been at the forefront of the statewide movement for implementing the middle school model since the school opened in 1987. The impetus for the development of a middle school came from the district and the state and was supported by the School of Education at the nearby University of Texas at El Paso (UTEP). Wiggs is a state-designated Mentor School. In this capacity, it serves as a laboratory for other schools, especially those wanting to implement the "middle school concept." Wiggs's mentor teachers participate in site-level training as well as professional development activities offered by the district and by UTEP.

Located near the Mexican border, Wiggs accommodates a constant influx of students from Mexico. Most of the students arrive at Wiggs literate in Spanish with previous formal schooling. In order to incorporate the newcomers, the school employs a Language Acquisition for the Middle School Program (LAMP), which consists of a sheltered English program with an intensive English as a second language (ESL) component for newcomer LEP students. The LAMP program is supplemented by Spanish language arts classes and implemented by teachers certified in ESL and their content area. Most of the teachers in the program are fluent in Spanish—the native language of their students. LAMP classes are smaller than regular classes, averaging between 14 and 15 students per class. Small class sizes allow teachers to provide intensive instruction to LEP students and monitor individual student progress.

Wiggs groups students into two families at each grade level and groups LEP students into two additional families called LAMP families.

Families allow students opportunities for instructional contact with a small number of faculty who can deliver curriculum and develop instructional activities appropriate to the students' stage of development. The five teachers in each family meet daily to discuss various topics, including plans for collective activities, problems with and rewards for individual students, and schoolwide activities. Teachers have in-depth knowledge of their students' school progress and family situations. Teachers are alert to signs of problems in any arena and work collaboratively with parents and students to find solutions.

The LAMP program is housed in two families—one for beginning LEP students, the other for intermediate LEP students. Students in the LAMP families span the three grade levels at the school. The program's structure allows staff the flexibility to move students from the beginning LAMP family to the intermediate LAMP family when they are ready. The program is also designed to accommodate newcomers arriving throughout the year. Students remain in LAMP classes only as long as it takes to prepare them to succeed in the mainstream instructional environment of the school. Once students are ready for the mainstream environment, they are assigned to one of the mainstream families at the school.

Students at Wiggs have seven academic periods, a homeroom period, and an advisory period. Teachers have an individual period each day for conferences or lesson preparation. The last period of the day is the advisory period for all students in the school. Advisories are smaller than the regular classes—some are as small as nine students. Teachers use this time to get to know their students, follow up on any changes in their behavior in school, and work with them on individual problems concerning teachers and their fellow students or issues outside the school.

Wiggs has implemented site-based management, supported by Texas's new accountability system. Representatives of the faculty, staff, parents, and the community form a school-level governing body called the Campus Improvement Committee. The committee prepares a yearly Campus Improvement Plan and makes decisions on the school's discretionary budget, school policies and activities, partnerships with the community, and strategies for involving parents and community members as partners in the school.

Wiggs teachers make use of innovative curriculum and instruction strategies. Thematic units make curricula more meaningful, and cooperative learning strategies are employed throughout the school both in classes for newcomers and in mainstream classes. Teachers of newcomer LEP students help their students master cooperative strategies, which are not typical of the schools they attended in Mexico. Students quickly become effective cooperative learners. Wiggs also implements themes around which the whole school plans activities. Individual families also plan the-

matic units, sometimes in conjunction with other families. Often, themes are linked to project-based activities in which students work cooperatively.

Professional development activities at Wiggs are designed according to a schoolwide needs assessment. Training is conceived of as long-term and integral to the school's vision, rather than a series of isolated, individual events. For example, Wiggs has established a relationship with the UTEP, allowing Wiggs teachers to participate in a mathematics institute that has helped restructure the school's mathematics curriculum. Teachers who have participated in off-site staff training in recent years have focused on implementing the middle school concept, by promoting effective use of student advisories and developing interdisciplinary units and alternative assessment measures. Multicultural education and language development represent two other target areas for professional development.

Through another UTEP program, 12 Wiggs teachers, designated as clinical technology teachers, received training in innovative instructional uses of computers. These teachers were assigned student teachers trained in instructional uses of technology and their classrooms were equipped with state-of-the-art technology.

Features of Exemplary Science and Mathematics Programs

The four schools profiled above demonstrate several different avenues for providing LEP students with innovative, grade level instruction. How have they have been able to include LEP students in their schoolwide efforts to upgrade science and mathematics curricula? Although each school is different, they share the following features:

- They are engaged in innovative approaches to science and mathematics education that are aligned with and assisted by national efforts to upgrade curricula for all students.
- They give LEP students access to these innovative science and mathematics programs.
- Their language acquisition and development programs for LEP students support, and are coordinated with, the exemplary science and mathematics programs.
- Their restructured school organization supports their innovative approaches to science and mathematics education.

Innovative Approaches to Science and Mathematics Education

The innovative approaches to teaching science and mathematics were manifestations of larger national and state level efforts to improve teaching and learning in science and mathematics. Most relied to some

extent on federal support for curriculum development, in particular the National Science Foundation (NSF) or Eisenhower funds for science education. The innovative programs included: Project 2061, a long term development project of AAAS, funded by numerous public and private sources; TERC's NSF project in Cambridge, Massachusetts, on scientific sense-making and instructional conversation; and the Texas science curriculum effort supported in part with federal Eisenhower funds. The California science curriculum framework provided the foundation for exemplary science instruction at one middle school in the study.

Project 2061, launched by AAAS in 1985, seeks to increase scientific literacy for the next generation of children in time for the return of Halley's Comet in the year 2061. A team of 300 scientists developed learning goals for all students, and those goals have been translated into benchmark standards for science, math, and technology for grades 2, 5, 8, and 12. The San Francisco Unified School District is one of six national sites participating in Project 2061 and is led by a district level staff. Teams of teachers design learning challenges in which heterogeneous groups of students need to accomplish a project within a given period of time. Students use science, math, social studies, and language arts to meet the challenge. The district office supports the faculty efforts in curriculum design and assessment of learning challenges. See the box below for an example of a learning challenge.

Project 2061

At Horace Mann Middle School, 100 eighth graders were challenged to create a "non-violent community for the year 2000" for their neighborhood in the Mission District in San Francisco. The students worked with four teachers and community mentors, such as a Latino architect, who offered expertise useful for the learning challenge. Five groups of 20 heterogeneously-grouped students were given a week to: develop a non-violent community that addressed a specified series of issues, build a scale model, write an essay, and present their non-violent community orally to the school and community. Students were challenged to address concerns such as energy, disposal of human and industrial waste, clean water and air, housing, care for the elderly and the very young, schooling, social institutions, energy-efficient transportation, and community crime control and justice. The scale models were presented to the community at large in an open-house assembly at which students took turns explaining their ideal community and answering questions. All students had a chance to present during the assembly.

TERC, a non-profit organization in the Boston area, has received NSF and OERI funding to study what and how LEP students learn in an

inquiry-based science classroom. Early TERC projects at Graham and Parks School examined the quality of drinking water at the school. The Graham and Parks/TERC project at the time of the site visit was devoted to biology, and, in particular, life systems of various organisms such as snails, hornworms, and ants.

The TERC staff develops extensive background material for the teachers at Graham and Parks. They attend 2-week summer programs and also bi-weekly seminars with all the teachers in the Boston area working on TERC project during the school year. In the seminars, teachers and TERC staff read scientific literature and analyze classroom practice using video tapes, transcripts of lessons, and samples of student work. TERC supplies materials for the student projects and helps provide support and guidance to teachers as they work through developing students' firsthand knowledge of an inquiry.

In Texas, Eisenhower funds have been used by the Texas Education Agency to develop Science 1 and Science 2, integrated science curricula for middle school teachers. Teachers receive special training and support in implementing Science 1 and 2 and teachers of LEP students have participated in Eisenhower-funded training opportunities.

The California science curriculum framework for middle school students provided a foundation for the exemplary science program at Hanshaw Middle School in Modesto. The state framework presents topics to be studied by students in seventh grade science, such as properties of air and water, biomass, food webs, biomes, and natural resources. Hanshaw teachers develop themes for instruction that incorporate the required elements as well as math, social studies, and language arts. Susan Kovalik & Associates was the external partner collaborating with Hanshaw teachers to develop thematic instruction and meaning-centered curriculum, and to teach life skills such as integrity, initiative, flexibility, effort, and cooperation. Kovalik & Associates received support from the Packard Foundation to develop their approach to teaching science, which is based on findings in brain research on how students learn.[5]

Many of these science and mathematics education improvement efforts emphasize the construction of meaning, experiential learning opportunities, and thematic instruction. For example, teachers at Graham and Parks use a method called "science talk" in which all students gather in a circle and discuss a pre-arranged topic relating to findings in their experiments. Science talk allows students to guide the discussion, develop topics, argue evidence, explore their findings, and formulate additional questions. The teacher plays a facilitative role but allows students to lead and introduce relevant topics. "Science talk" is conducted primarily in Haitian Creole, with some clarification in English as needed.

Most study sites build science learning into thematic instruction units. For example, Wiggs Middle School developed a thematic unit on chiles. In

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social studies, students learned about both the historic and ongoing tensions between Mexico and New Mexico over the crop. In math, students made graphs plotting the relative heat of the chiles, studied crop yields in different parts of the world, and computed acreage and yield of chiles. They also developed salsa recipes using fractions, adjusting recipe proportions for smaller and larger batches of salsa. In Spanish class, students read literature about the chile god and composed their own stories extending the myth. In science, students studied chiles during the unit on green plants: they dissected chiles and learned about chile seed dispersal.

At Horace Mann, the students performed a Project 2061 learning challenge about feeding a hungry world. They built a garden on the roof of the school, grew food, and studied the crops they cultivated. Students planned the garden, researched the organic methods of growing vegetables, measured yields, kept records, and planned the food distribution. They gave food to homeless shelters in the community and took some food home to eat.

Giving LEP Students Access to Innovative Science and Mathematics Programs

The science and mathematics programs in the study sites have been able to include LEP students in the innovative approach to learning for several reasons. In some cases, such as the TERC program at the Graham and Parks School, the innovative science program has been designed explicitly for students learning English. At Graham and Parks, the successful approaches used with LEP students have been adapted and used with the wider school population. In other cases, such as Project 2061 or the Eisenhower science programs in Texas, LEP students have not been the principal intended beneficiaries of the innovative science instruction, but have been included during implementation at the school sites and thus have benefited from national science curriculum reform efforts.

Having faculty with expertise in second language acquisition, who are often fluent in the students' native language, is another reason the schools were able to include LEP students in innovative science instruction. Teachers at study sites reported that science courses offered excellent opportunities for LEP students to produce and develop English language skills. Students found science motivating as they produced oral and written language to negotiate meaning in science lessons with peers and teachers.

The language of instruction in science can be the LEP students' primary language, as observed in Spanish science and math core classes at Hanshaw Middle School and science classes at Horace Mann. Another option is to present science in English by teachers who are fluent in the primary language of LEP students and thus can clarify meaning in the primary language. Wiggs Middle School and Hanshaw Middle School teach sheltered science to LEP students in this way. Graham and Parks allows

students to use either Haitian Creole or English in learning science, and bilingual teachers provide clarification in both languages. Clustering advanced LEP students who are speakers of the same primary language in mainstream classes is a strategy used at Hanshaw Middle School and Graham and Parks in eighth grade science. In both cases, the teachers have had training in second language acquisition, but are not fluent in the students' primary language. All of these strategies provide access to grade level science and mathematics instruction for LEP students in middle school. The box below gives an example of clustering of LEP students.

Hanshaw Middle School 8th Grade English Mainstream Science Class

At Hanshaw, an eighth grade science class studied salinity and temperature in currents in a fully equipped science lab. Of 31 students in the class, eight were LEP students. The teacher asked each student group to select one person to gather equipment, and directed the students to take notes on the results so they could answer questions. The teacher reminded the class that they had resources other than the teacher, such as the lab sheet and others in their group. She told the students that if questions remained after those sources had been consulted, she would be glad to help.

The students were accustomed to working in groups and were comfortable dividing up tasks. The teacher moved from group to group encouraging students to consider their results from various perspectives, by asking questions such as: "What do you think will happen?" "Why do you think they are not mixing?" "How is this experiment like the salinity one?" "What do the two experiments together tell us about the ocean?" LEP students in the class were concentrated in two of the groups. At least one student needed help in Spanish and another student in the group translated the directions or answered questions in Spanish. The groups with LEP students performed the experiments as proficiently as the non-LEP groups, but they needed more time to answer the questions and they consulted more with their peers than did the native English speakers. Although the teacher spent time with each of the groups, she took a little more time with the groups that included LEP students.

Language Acquisition and Development for LEP Students

LEP students' access to the innovative science curricula at the exemplary sites was supported by a carefully planned language program that featured trained faculty, student grouping strategies, team teaching, and careful attention to the process for transitioning students to all-English instruction.

Faculty, knowledgeable about second language acquisition, and sometimes fluent in the students' native language, enabled the site schools to include the LEP students in their innovative science curriculum. The lack of trained faculty appears to be a major barrier in preventing many other schools from offering grade level science instruction to LEP students.

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Teachers at the exemplary sites often grouped students for cooperative learning assignments. They deliberately mixed the LEP students with different levels of English to ensure that more advanced English speakers could assist beginning English learners. Another grouping strategy to cluster speakers of the same native language in mainstream English classrooms and allow them to confer in their native language. Cooperative learning provided opportunities for students to learn from one another, to conduct observation of natural phenomena, and to produce oral and written language. Cooperative learning was a prominent feature in all the exemplary schools studied.

Team teaching was used effectively at Graham and Parks by pairing an English-speaking teacher with a Haitian Creole bilingual teacher in the grade 5 through 8 program. Having two language role models expanded the capacity in the classroom for language development. Both teachers participated in TERC professional development opportunities that enabled them to do scientific explorations. Pairing two core teachers, one for math and science and one for social studies and language arts, helped Hanshaw teachers implement thematic units across curricular areas. Core teacher teams used Spanish for Spanish-speaking LEP students or sheltered instruction methods for advanced Spanish speakers and speakers of Southeast Asian languages.

The schools provided multiple pathways for students to make the transition from LEP programs to mainstream all-English instruction. Approaches were tailored to the unique needs of individual LEP students: These schools did not adopt a "one-size-fits-all" approach. Hanshaw Middle School, for example, offered LEP students primary language science, or sheltered science, or regular science taught in English by a teacher with special training in second language acquisition. Horace Mann offered science in Spanish to students learning English or seeking to develop their Spanish literacy levels, sheltered science in English with a Cantonese-speaking teacher to Cantonese students, or science in English. Graham and Parks's grade 5 through 8 bilingual class sent advanced LEP students into a mainstream English science class clustered as a group.

Students making the transition from LEP programs to mainstream English classrooms received instructional support such as after-school tutorials and homework centers staffed by volunteers and staff fluent in the students' native languages. The students who were interviewed in focus groups valued such opportunities and felt that this kind of support greatly enhanced their ability to be successful in mainstream English science classes.

School Restructuring

The exemplary science and mathematics programs examined at the four case study schools took place in a broader context of schoolwide

reform. While elements of school reform were implemented in unique ways in the four schools, some common themes emerged. Key reform elements included school-based decision making, creation of smaller school units, and innovative uses of time.

The devolution of power to the school site and away from centralized control at the district, state or federal level, is a key principle in school reform. School-level personnel are being given more discretion over the school budget, personnel decisions, curriculum, assessment, and uses of time.[6] School-level control was particularly important for the case study schools as they developed programs to meet the complex needs of their LEP students. Decision-making procedures involved teachers, parents, and community members in setting school priorities, in curriculum development, in scheduling, in determining what professional development was needed, and in allocating resources for LEP students and all students. Graham and Parks had a long history of site-based decision making that extended to selection of staff by teachers and parents. At Horace Mann and Hanshaw, the principal shared power over the discretionary budget with teachers. Wiggs implemented a Texas statewide site-based management approach.

The exemplary sites developed smaller schooling units that enabled teachers to work collaboratively and to foster more personal connections among students, teachers, and parents. The three middle schools restructured their schools into a number of smaller organizational units or "schools-within-schools," called "families" at Horace Mann and Wiggs and "houses" at Hanshaw. Within these smaller units, for example, 100 students and four teachers worked as a team for instruction. The teachers planned curriculum and thematic units together. Students spent sustained time with the same small number of teachers. At Graham and Parks, the combined grade 5 through 8 classroom included two teachers with 23 students. The ungraded class formed an intimate setting for science in which students grew to know one another, and their teachers, quite well.

The exemplary schools used the resource of time very carefully to further their instructional goals. Time was viewed as a precious resource to be guarded for learning. Teachers protected their students' time, creating sustained periods for in-depth project work in science, laboratory experiments, and thematic learning. The exemplary schools did not allow rigidly predetermined short blocks of time to supersede learning activities. Interruptions and fragmentation of the school day were firmly avoided.

Protecting time to learn was accomplished in a variety of ways. At Graham and Parks, the two 5th through 8th grade teachers controlled the use of time during the school day and allocated substantial blocks of time for social studies, language arts, and science projects. Horace Mann and Hanshaw Middle Schools had a schoolwide schedule that set aside blocks of time for core content areas. Hanshaw scheduled blocks of 90 minutes each for a combined class of mathematics and science or language arts and

social studies. Horace Mann scheduled two 105-minute academic blocks each day with each academic class meeting every other day. Longer time blocks allowed teachers to plan for more complex lessons and problem-solving activities and provided opportunities for science experiments, research activities, thematic projects, and sustained reading and writing activities.

Another time strategy was to extend the school day through after-school learning opportunities. Both Hanshaw and Graham and Parks provided after-school homework and tutorial programs for LEP students, staffed with individuals fluent in the students' native language. At Graham and Parks, advanced LEP students studied science in their grade 5-8 bilingual class and in a mainstream class taught in English. The Haitian Creole LEP students relied on after-school tutorial help from Creole-speaking staff to assist them with their homework in the English science class. The students regarded the after-school support as critical to their success in mainstream science, which had more challenging English reading and writing requirements.

Teacher collaboration enabled other innovations to develop and flourish. The exemplary schools organized time for teachers to plan together and engage in professional development. The case study schools relied upon an open collegial environment to develop their programs and foster a sense of professionalism. At all of the case study sites, teachers attributed much of their success in implementing dramatic changes to an atmosphere of collegiality and a shared vision, both of which grew out of collaborative teamwork.

Conclusion

The School Reform and Student Diversity Study provides some important lessons about how school reform can support effective science and mathematics instruction for students who are learning English. The study demonstrates that concepts of reform in curriculum and instruction can be effectively used with LEP students and provide benefits to them in learning science and learning English. Certain elements of school reform appear to be particularly valuable in overcoming barriers to teaching LEP students science and mathematics. These include school-based decision making over resources and time, creation of smaller school units for learning, innovative uses of time that protect and extend LEP students' time to learn, and teacher collaboration that enables joint curriculum planning across grade levels, classes, and subject areas.

While school reform elements are important supports for science learning opportunities, the presence of well-conceived and well-imple-

mented language development programs for LEP students is equally important. Availability of qualified faculty, creation of multiple program pathways for making the transition to all-English programs, innovative ways to use teachers as language role models, and instructional support for students as they transition to all-English instruction provide the means for LEP students to gain access to grade-level science curriculum.

The exemplary schools were identified through an extensive nationwide search. Study team members encountered numerous obstacles in identifying schools with significant populations of students whose first language is other than English who were involved in high quality scientific learning efforts. The schools that were selected for intensive study were not working in isolation; rather, they were part of larger national efforts to upgrade science and mathematics education. For the most part, these efforts were supported with federal funds, notably NSF grants or support from state-level Eisenhower grants for science education. In some cases, such as the TERC partnership with Graham and Parks Schools, the national effort was directed at science learning for LEP students. In other cases, such as Project 2061 and Science 1 in Texas, an inclusive philosophy served to draw in LEP students enrolled in the schools that were participating in the science projects.

While the results of this study indicate that some progress has been achieved by national and statewide efforts to upgrade science and mathematics education for LEP students, much more needs to be done to make the learning opportunities observed at these four schools widely available to LEP students nationwide. Federal and state roles will be very important in conceptualizing, developing, implementing, and disseminating effective approaches to upgrading science instruction for students who are learning English.

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Notes

1 In 1990, the Office of Educational Research and Improvement (OERI) of the U.S. Department of Education issued a Request for Proposal (RFP) to identify and study exemplary school reform efforts involving the education of language minority students. The RFP directed the project to focus on language arts in grades 4 through 6 and math and science in grades 6 through 8. The project analyzed the context of school reform and how school reform affects the schoolwide curriculum and program of instruction for LEP students. The study was conducted

by the National Center for Research on Cultural Diversity and Second Language Learning at the University of California, Santa Cruz, in collaboration with BW Associates of Berkeley, California. (The author was a consultant to BW Associates.)

The full study findings are reported in three volumes: *School Reform and Student Diversity—Volume I: Findings and Conclusions* reviews the context and methodology of the study, summarizes key features of each case study of eight exemplary schools, presents analyses of case study findings across these sites, and offers policy recommendations. The case study sites are described in detail in *Volume II: The Case Studies. Volume III: Technical Appendix* presents the research design and methodology of the study. The research papers commissioned for the study are published in a book edited by McLeod (1994), *Language and Learning: Educating Linguistically Diverse Students.*

2 The term limited English proficient (LEP) is defined in state statutes to be children whose first language is a language other than English. Children are classified LEP when their levels of oral English fluency, English reading, and writing skills are such that they require specially designed instruction to teach them English and core content.

3 Six indicators of excellence were applied: (1) Innovation—The school departs from standard instruction, scheduling, organization, and/or curriculum segmentation in order to facilitate program goals; (2) Embedded—the practices for LEP students are not isolated, but are part of the entire school program; (3) High standards—school staff articulate the philosophy of the program, which includes a vision of quality education for LEP students; (4) Longevity—the school's use of the identified practices is a serious long-term effort; (5) Qualified staff—staff training and expertise are appropriate to the practices being implemented with LEP students; and (6) Generalizability—the school serves students who are fairly typical of LEP students nationally and its situation is not so special as to preclude other schools learning from it.

4 For more information on TERC's approach to science learning see Research Report No. 3 and Research Report No. 14 in this report series.

5 See Kovalik, S.J., & Olsen, K.D. (1994). *Kid's-eye view of science: A teacher's handbook for implementing an integrated thematic approach to teaching science K-6.* Kent, WA: Center for the Future of Public Education.

6 Another OERI School Reform study examined site-based decision making. See Wohlstetter, P., Smyer, R., & Mohrman, S. A. (1994). New boundaries for school-based management: The high involvement model, *Educational Evaluation and Policy Analysis, 16,* (3), pp. 268-86.

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